ELECTRICAL
& COMPUTER
ENGINEERING

ECE-595 Network Softwarization

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Definition of Edge Computing

EDGE COMPUTING IS THE PLACEMENT OF DATA CENTER-GRADE NETWORK, COMPUTE & STORAGE

Closer to ENDPOINT DEVICES

TO IMPROVE SERVICE CAPABILITIES

Optimize TCO

Comply with Data Locality

And reduce application Latency

The Edge Is the

Outmost layers of

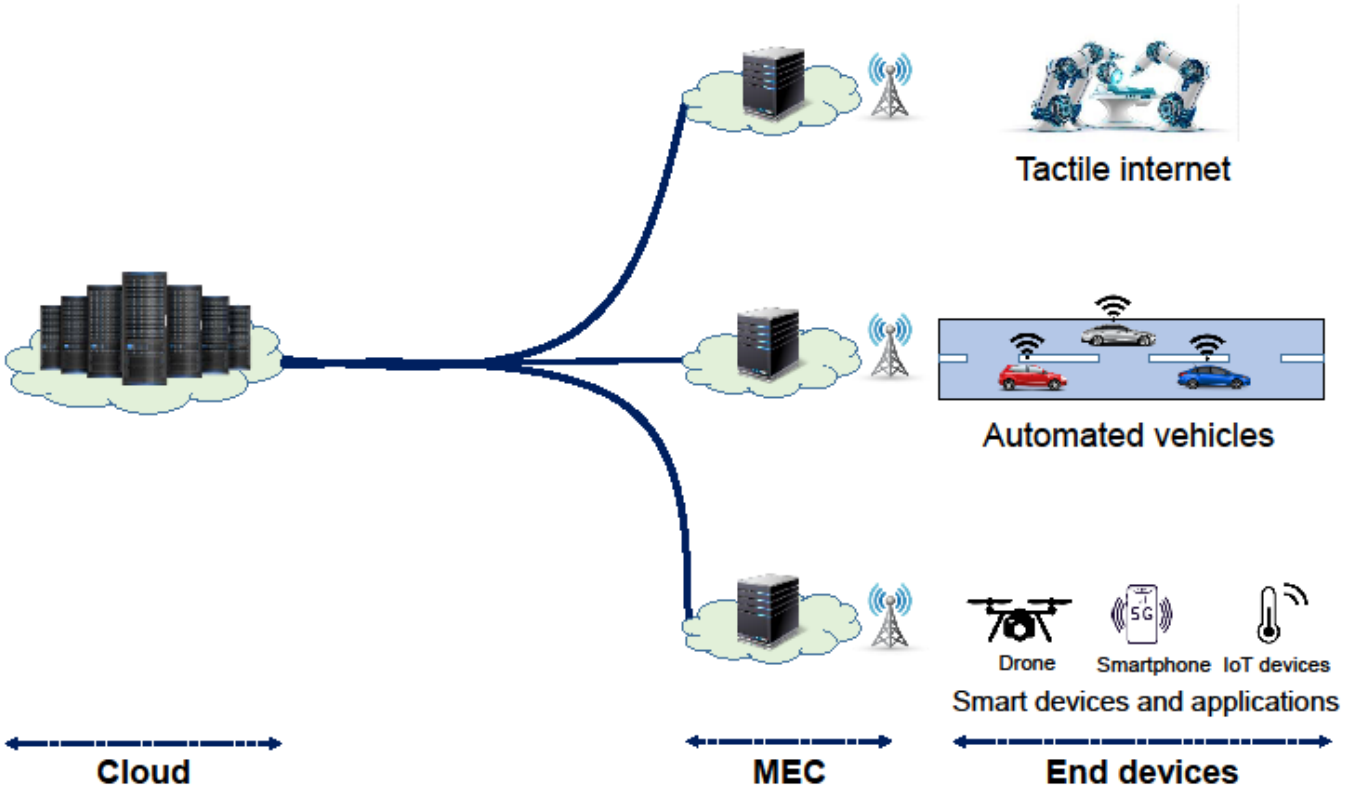
Processing or Network

BEFORE TRANSITION TO THE ENDPOINT

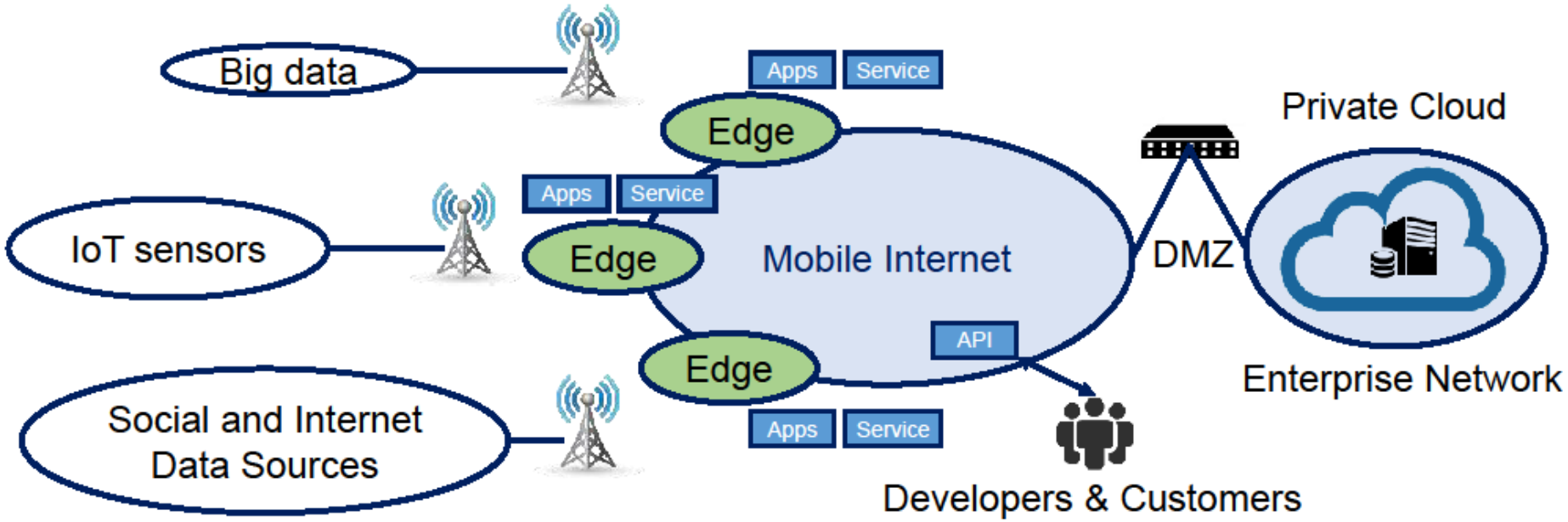
OR

Another Network

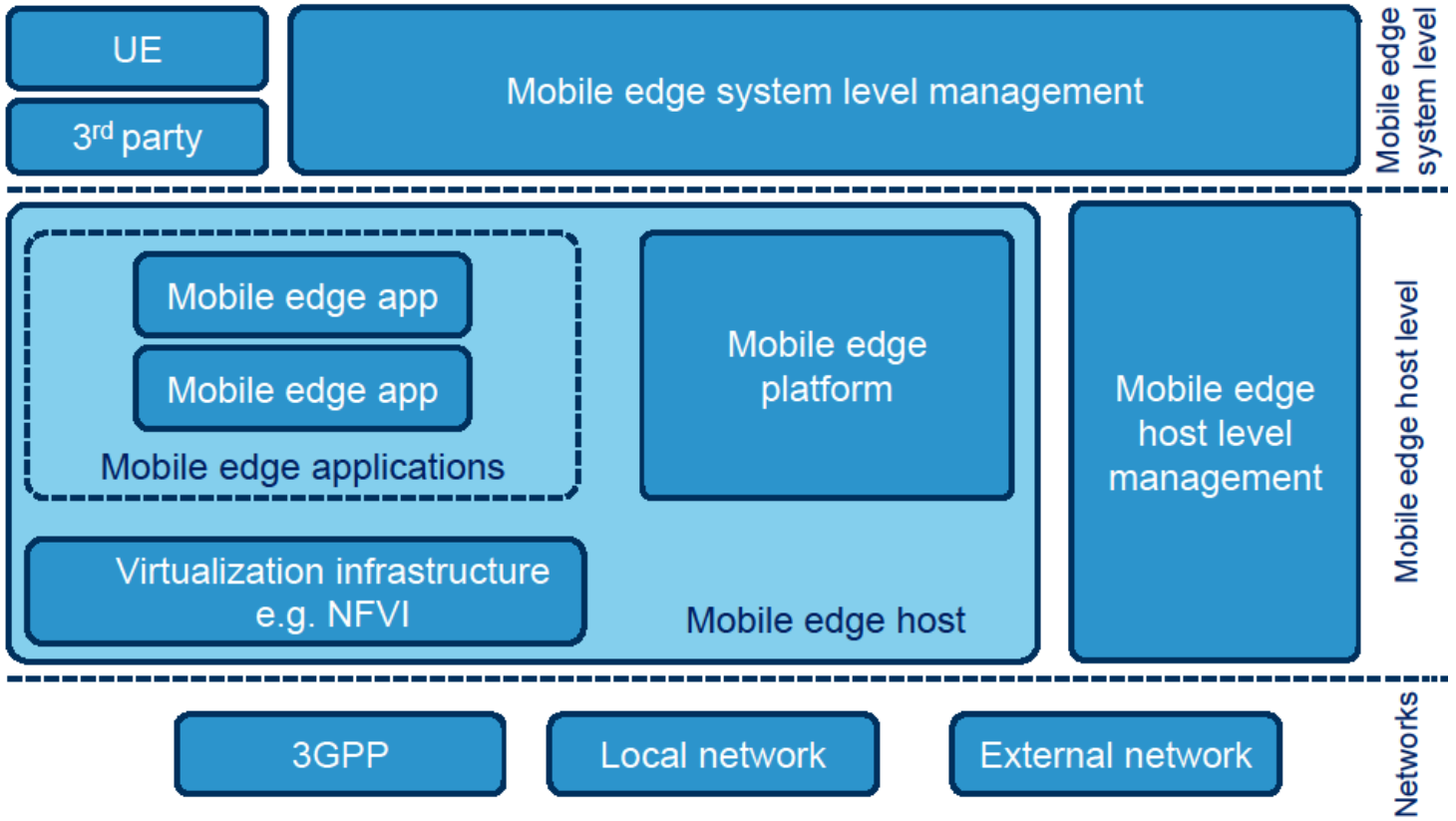
Three-layer architecture. MEC, cloud, and mobile device.



MEC architecture



Reference MANO architecture for MEC



Edge Characteristics


Low Latency, Real Time, Optimized Infrastructure and Rapid Response


Massive Various Data Storage and Movement, Data Sovereignty


Enhanced Security and Data Privacy


Context or Location Awareness, Localization


Multi-Access Networking across Large-Scale and Small-Size Sites: Unreliable, Limited, High-Bandwidth


Intelligence, Smartness, Autonomy, Zero-Touch, Self-X

Typical implementations of edge computing

Definition of the implementations

Fog computing(FC): “A decentralized Computing infrastructure based on Fog Computing nodes (FCNs) placed at any point of the architecture between the end devices and the cloud. The FCNs are heterogeneous in nature and thus can be based on different kinds of elements including but not limited to routers, switches, access points, IoT gateways as well as set-top boxes.”

Mobile/Multi-access Edge Computing(MEC): “To bring computational and storage capacities to the edge of the network within the Radio Access Network to reduce latency and improve context awareness. The MEC nodes or servers are usually co-located with the Radio Network Controller or a macro base-station. The servers run multiple instances of MEC host which has the capabilities to perform computation and storage on a virtualized interface.”

Definition of the implementations – Cont'd

Cloudlet(CC): "Treated as "data center in a box" running a virtual machine capable of provisioning resources to end devices and users in real time over a WLAN network. The services are Cloudlets are provided over a one-hop access with high bandwidth, thus offering low latency for applications."

Reference:
[1] Koustabh Dolui and Soumya Kanti Datta, "Comparison of Edge Computing Implementations: Fog Computing, Cloudlet and Mobile Edge Computing". 1-6. 10.1109/GIOTS.2017.8016213.

Characteristics of the implementations

Type of Implementation	FC	MEC	CC
Location	Near end device, dense and distributed	Radio Access Network Controller/Base station	Local/Outdoor Installation in one place
Device	Routers, Switches, Access points, gateways…	Servers running in base station or CO	Compact-size data centers
Access Mediums(mostly)	WiFi, LTE, ZigBee, MQTT, Bluetooth…	WiFi, LTE…	WiFi…
Logical Proximity	One/multiple hops	One hop	One hop
Ability for near-real-time Interaction	High	Medium	Medium
Multi-tenancy	Supported	Supported	Supported
Computation power	Medium	High	High

Characteristics of the implementations

Type of Implementation	FC	MEC	CC
Power Consumption	Low	High	Medium
Context Awareness	Medium	High	Low
Coverage	Low	High	Low
Server Density	Medium	Low	High
Cost/CAPEX	Low	High	Medium
Traffic Continuity	High	Medium	High
Active users	High	Medium	Medium

References:
[1] Koustabh Dolui and Soumya Kanti Datta, “Comparison of Edge Computing Implementations: Fog Computing, Cloudlet and Mobile Edge Computing”. 1-6. 10.1109/GIOTS.2017.8016213.
[2] Eugen Borcoci, “Fog Computing, Mobile Edge Computing, Cloudlets - which one?”, 2016
[3] Baktir, Ahmet Cihat & Ozgovde, Atay & Ersoy, Cem. (2017). How Can Edge Computing Benefit from Software-Defined Networking: A Survey, Use Cases & Future Directions. IEEE Communications Surveys & Tutorials.

Edge use case overview

Edge computing represents a potential value of $175 billion to $215 billion in hardware by 2025.

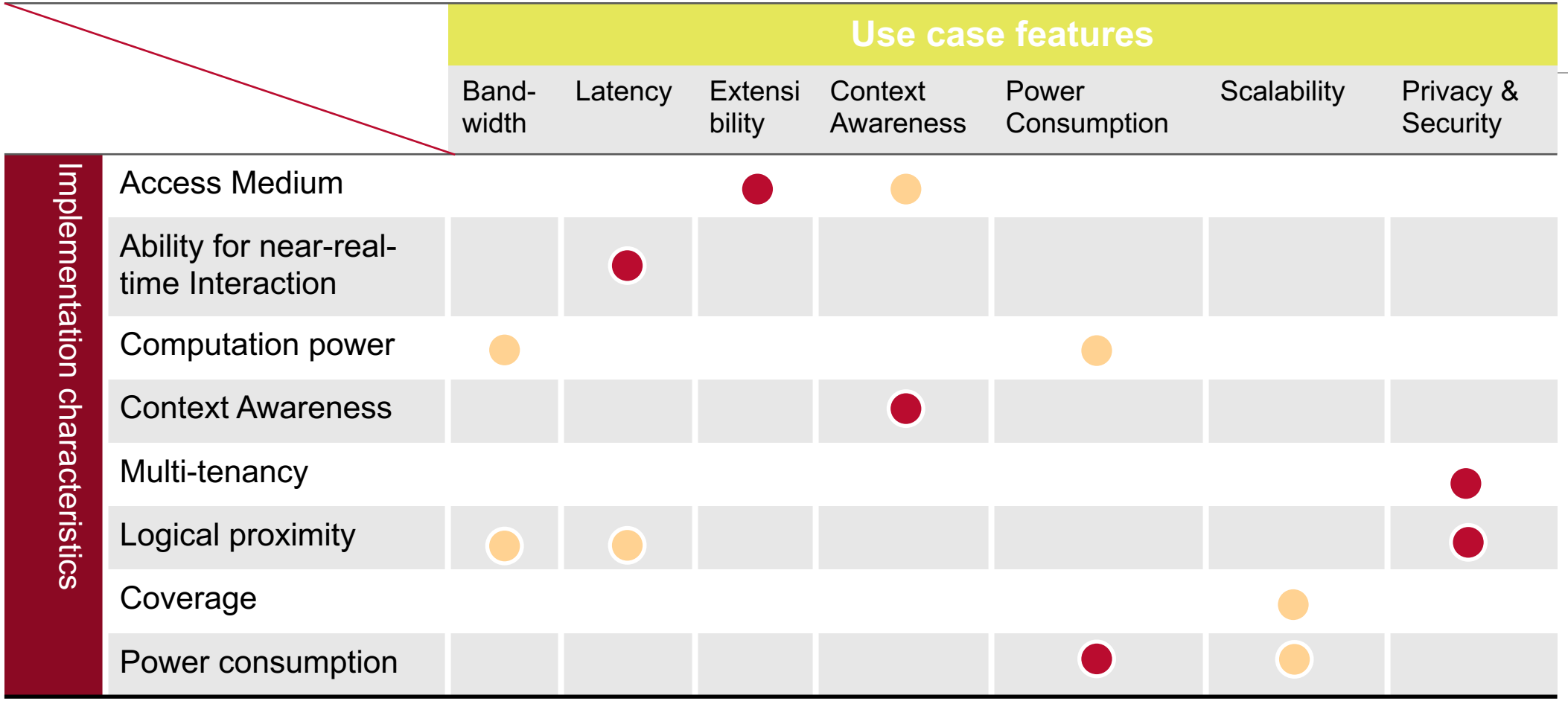
Industry	% of total edge use cases	2025 hardware value,[1] $ billion
Travel, transport, and logistics	24	~35–43
Cross-vertical	9	~32–40
Retail	10	~20–28
Media and entertainment	1	~17–25
Public sector and utilities	10	~16–24
Global energy and materials	13	~9–17
Advanced industries	10	~5–13
Healthcare	10	~5–13
Infrastructure	6	~4–11
Chemicals and agriculture	5	~4–11
Banking and insurance	1	~2–7
Consumer	4	~1–5

Total: ~$175 billion–$215 billion

[1]Hardware value includes opportunity across the tech stack (ie, the sensor, on-device firmware, storage, and processor) and for a use case across the value

Reference:
[1] https://www.mckinsey.com/industries/high-tech/our-insights/new-demand-new-markets-what-edge-computing-means-for-hardware-companies

Relationship between edge implementation and use case

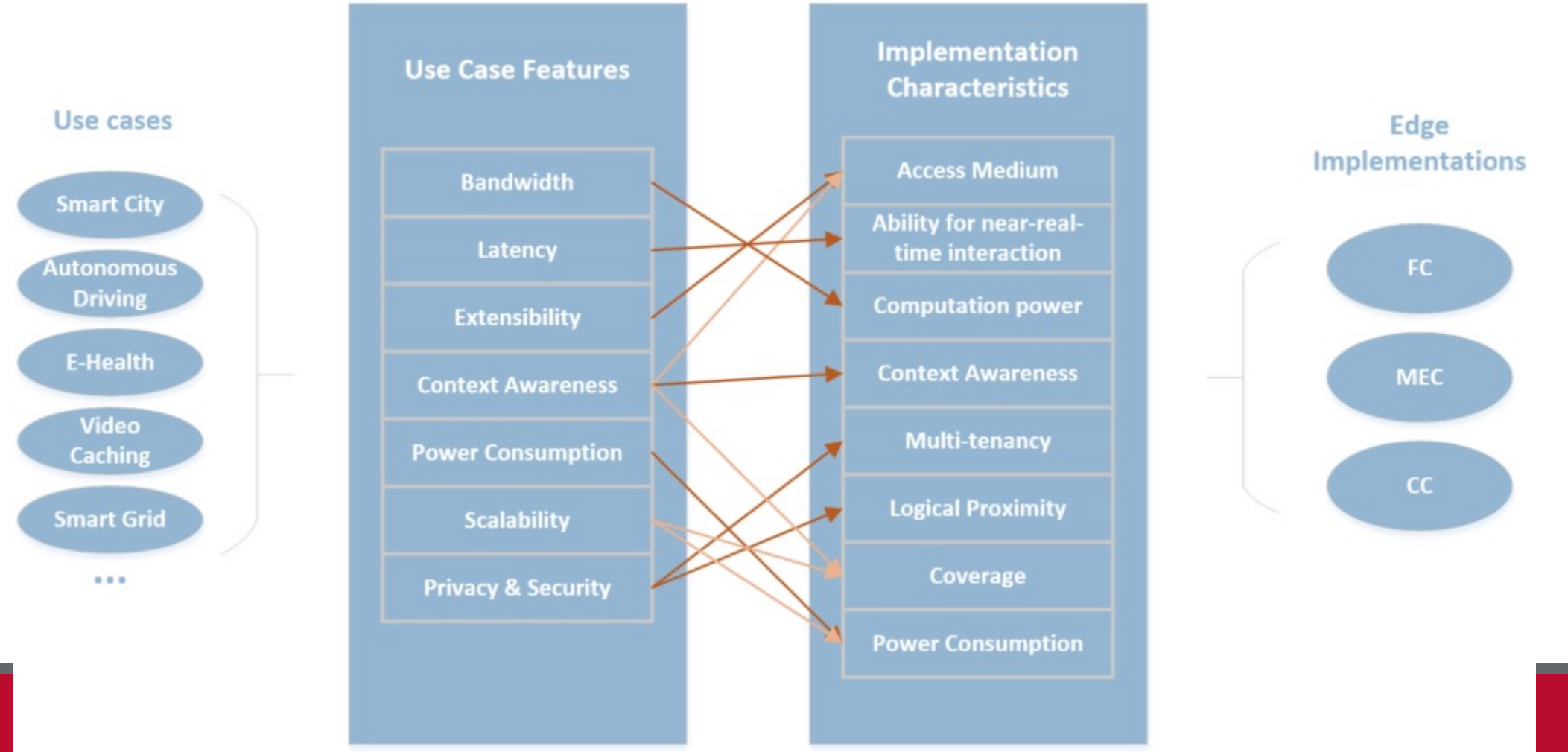


Some typical use cases

Features	Use cases						
	Smart Cities	RAN-aware Context Optimization	Augmented Reality	E-Health	Autonomous Vehicles	Smart Grid	Video Caching & Analysis
Bandwidth	●	●	●	●	●		●
Latency	●	●	●	●	●	●	●
Extensibility	●	●	●	●			●
Context Awareness	●	●	●		●		●
Power Consumption	●	●	●		●		●
Scalability	●	●	●	●			●
Privacy & Security	●	●	●	●	●	●	●

● Critical ● Depends

Work Flow

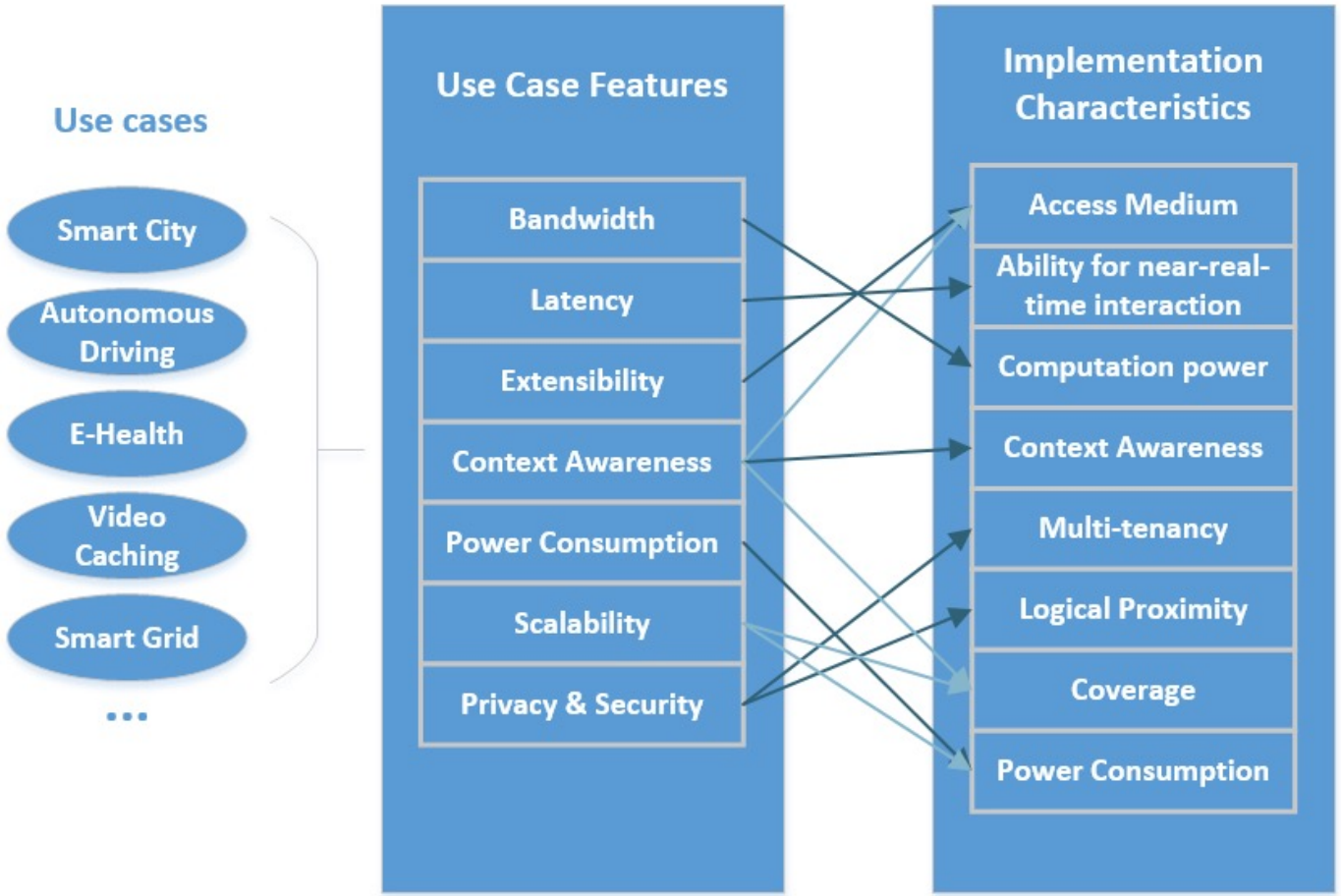

Use cases
Smart City
Autonomous Driving
E-Health
Video Caching
Smart Grid
...
Use Case Features
Bandwidth
Latency
Extensibility
Context Awareness
Power Consumption
Scalability
Privacy & Security
Implementation Characteristics
Access Medium
Ability for near-real-time interaction
Computation power
Context Awareness
Multi-tenancy
Logical Proximity
Coverage
Power Consumption
Edge Implementations
FC
MEC
CC

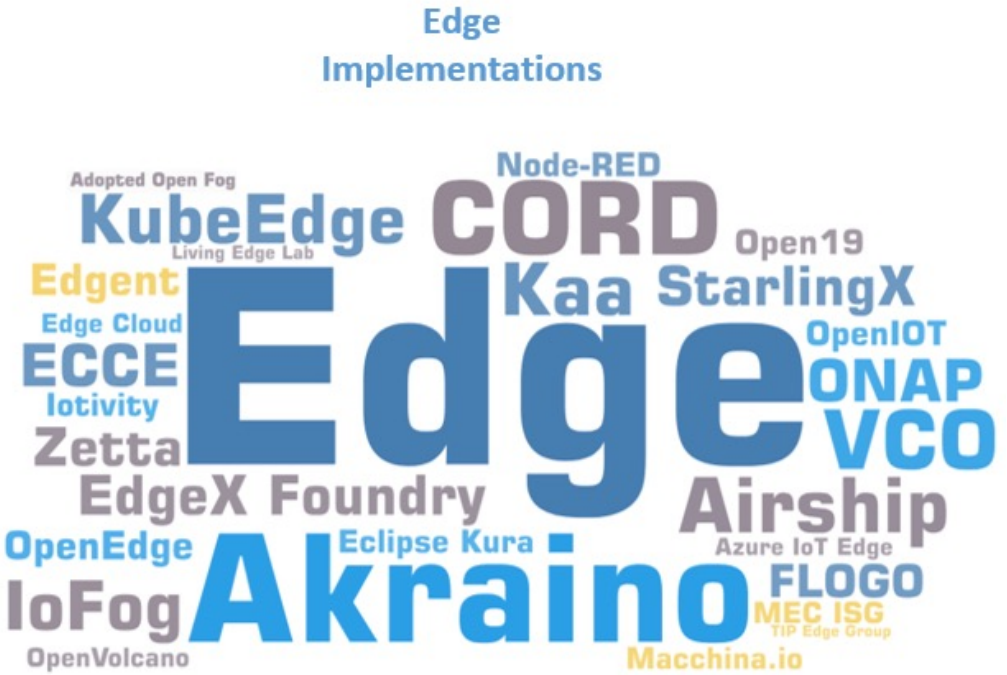
Recommendation for the use cases

Use Cases	Recommendation
Smart Cities	FC + MEC
RAN-aware Context Optimization	MEC
Augmented Reality	MEC/CC + FC
E-Health	FC
Autonomous Vehicles	FC + MEC
Smart Grid	FC
Video Caching & Analysis	MEC/CC

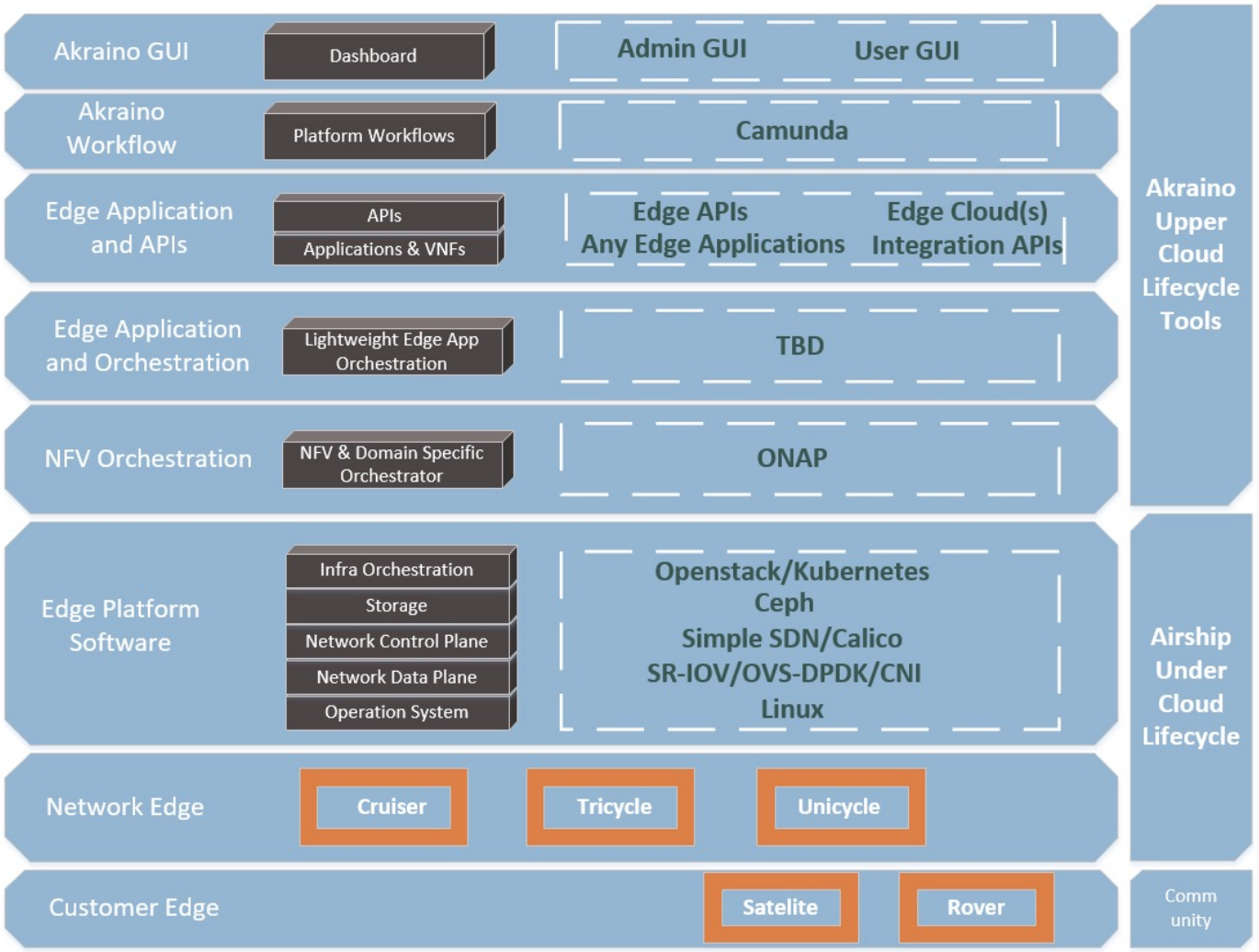
Open source projects available in the market

Regarding the projects…





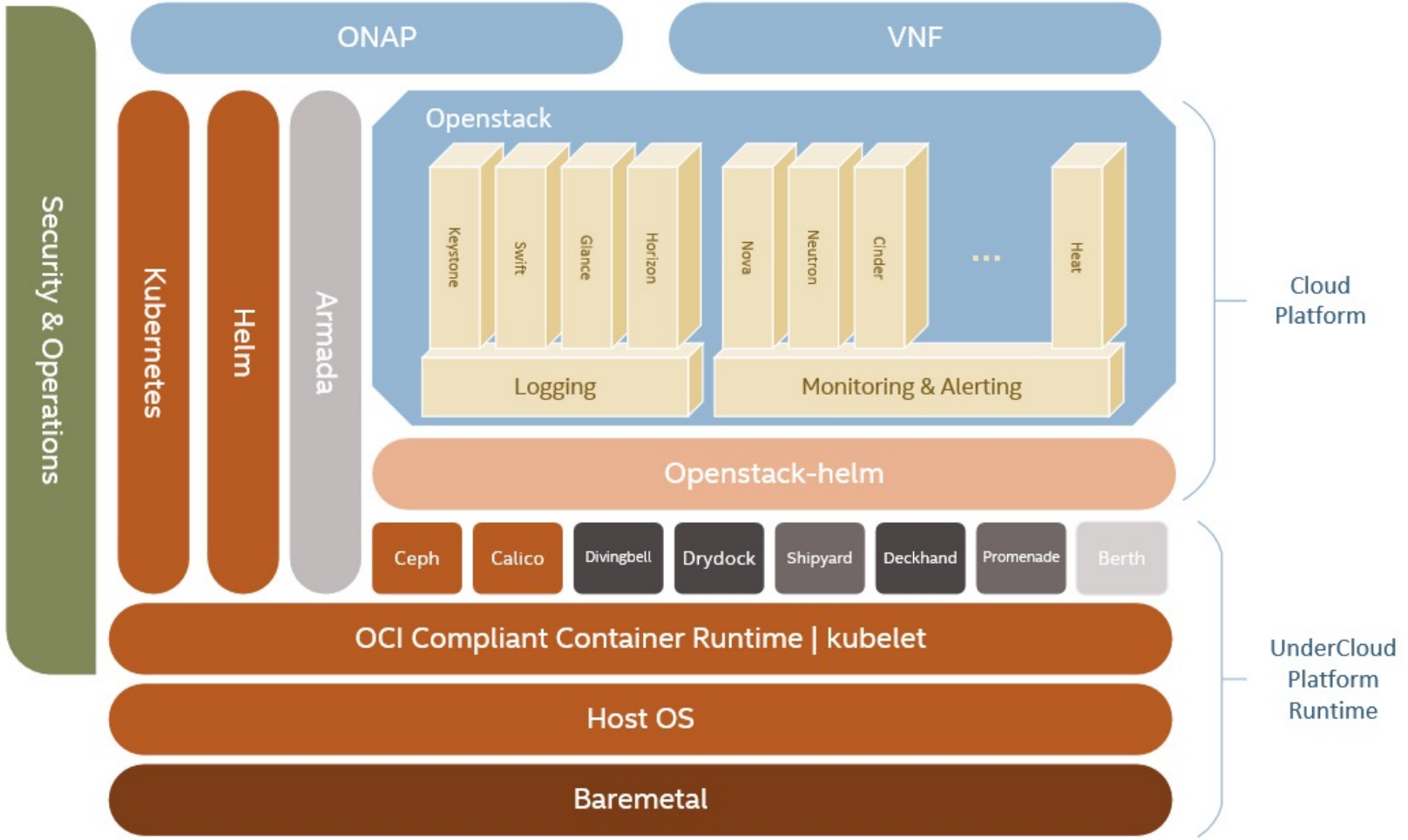
Akraino Edge Stack



" Fully integrated edge infrastructure "

" Intend to develop solutions and support of carrier, provider and the IoT networks "

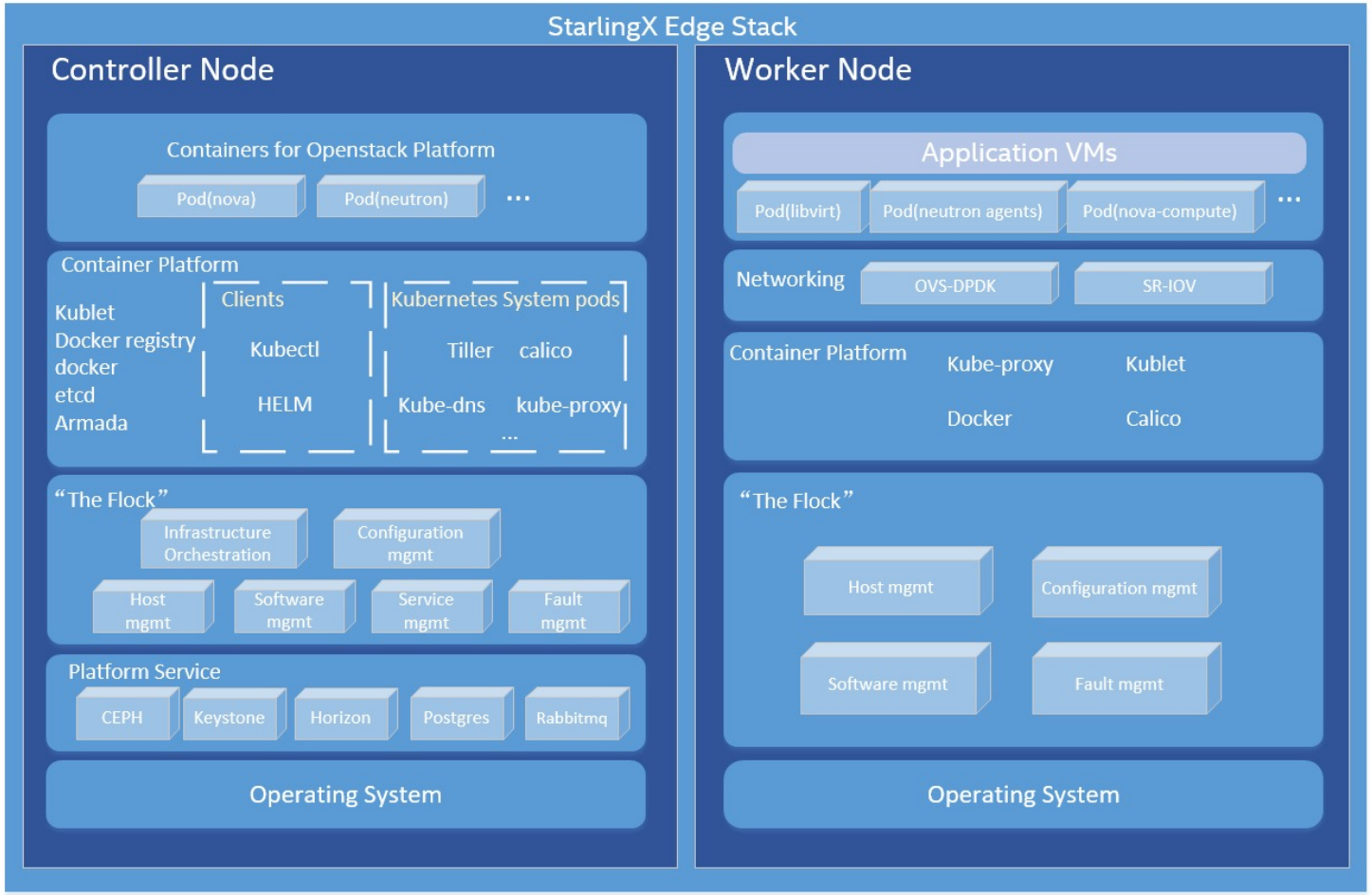
Airship



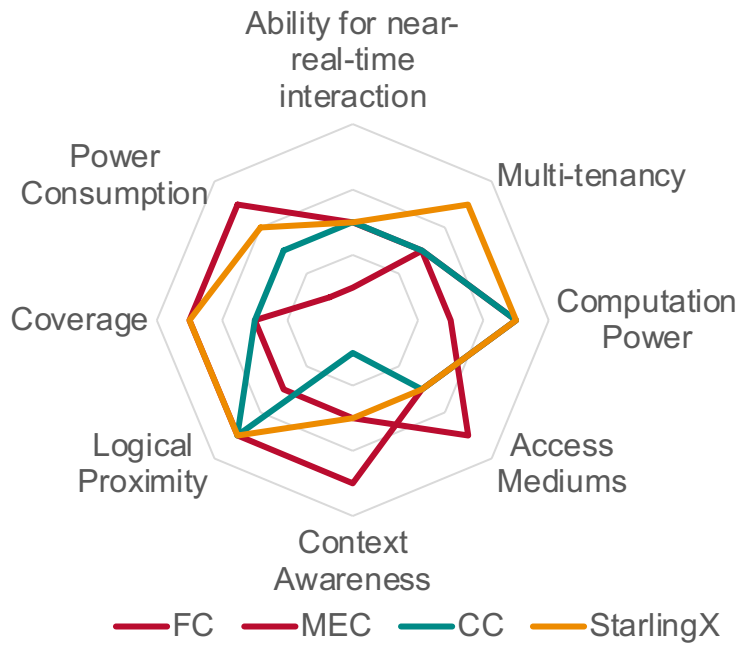
"Declarative, YAML-driven deployment"

"The implementation of Openstack on Kubernetes (OOK)"

StarlingX



"A deployment-ready, scalable and highly reliable edge infrastructure software platform"



Evaluation of StarlingX

China Unicom, together with Intel, 99Cloud build a new ME-IaaS (Mobile Edge-Infrastructure as a Service) based on the StarlingX.[1]

The approved Akraino blueprint that submitted by Tencent on connected vehicle has StarlingX proposed with TARS.[2] StarlingX is also proposed to be used in another blueprint submitted by WR on Far Edge Distributed Cloud.[3]

China Mobile Suzhou Software has evaluated StarlingX for its edge and cloud plan, and China Mobile Research Institute and Intel experimented vCPE onboarding on top of ONAP with StarlingX.

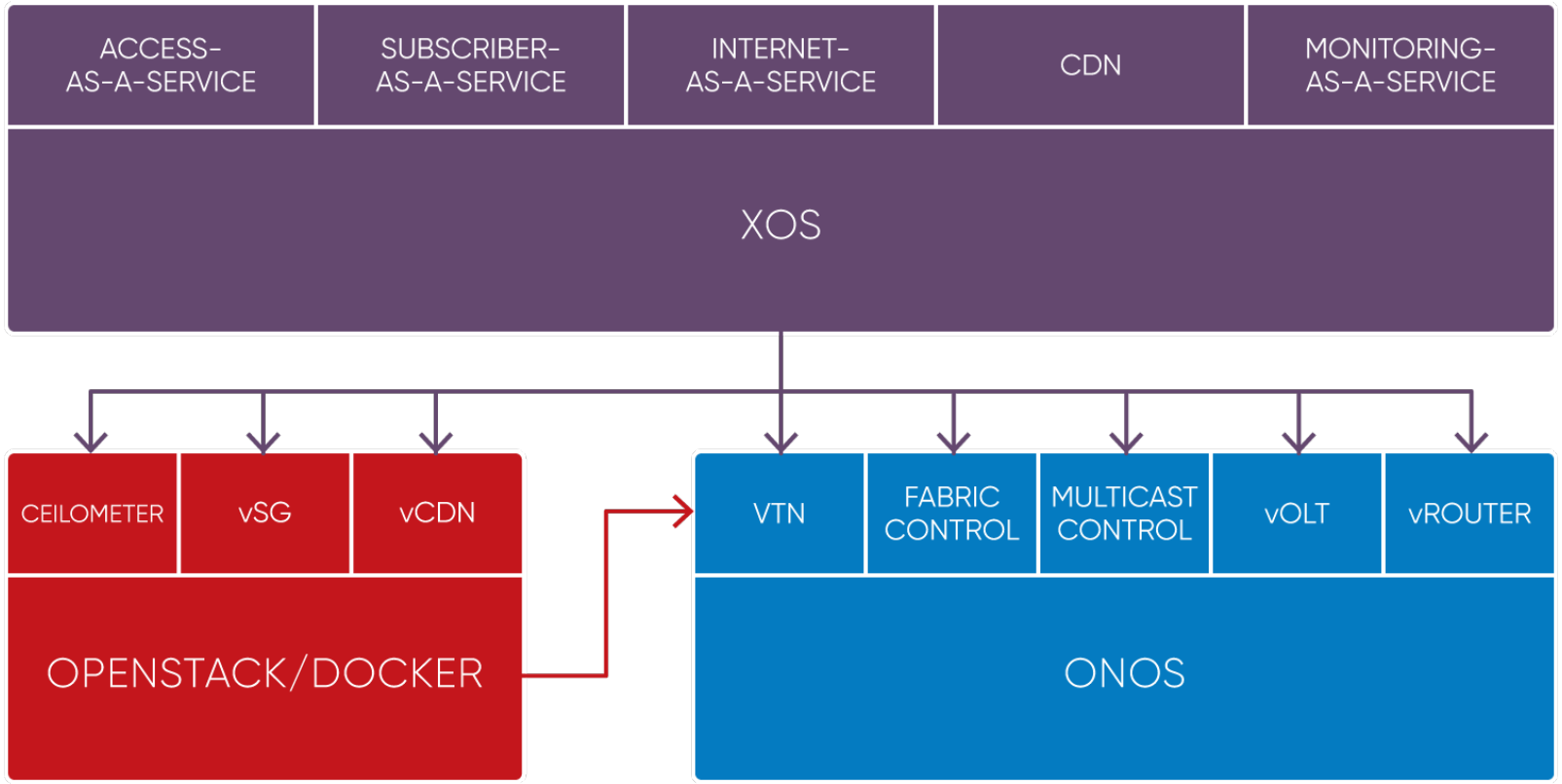
China Telecom Research Institute Guangzhou has evaluated StarlingX as a candidate for its edge solution

[1] Chinese ver: https://mp.weixin.qq.com/s/dlOpeo1Le5HEYCiSt3yUxg

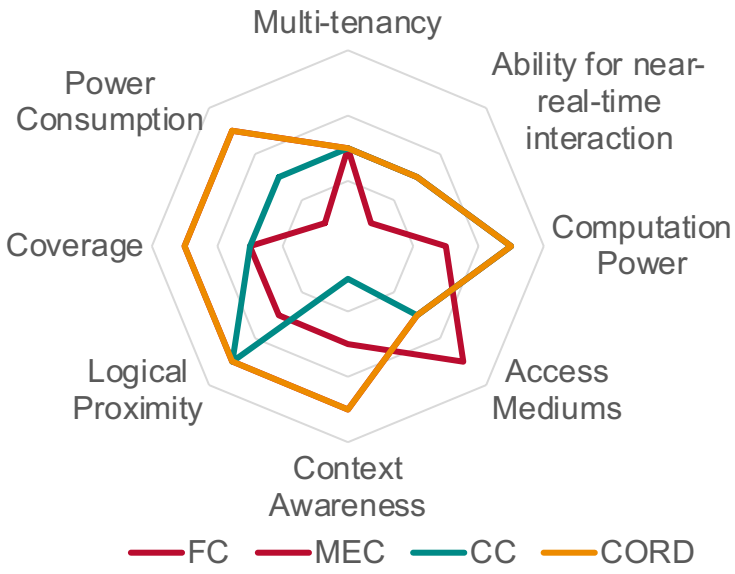
[2] https://wiki.akraino.org/display/AK/StarlingX+Far+Edge+Distributed+Cloud

[3] https://wiki.akraino.org/display/AK/Connected+Vehicle+Blueprint

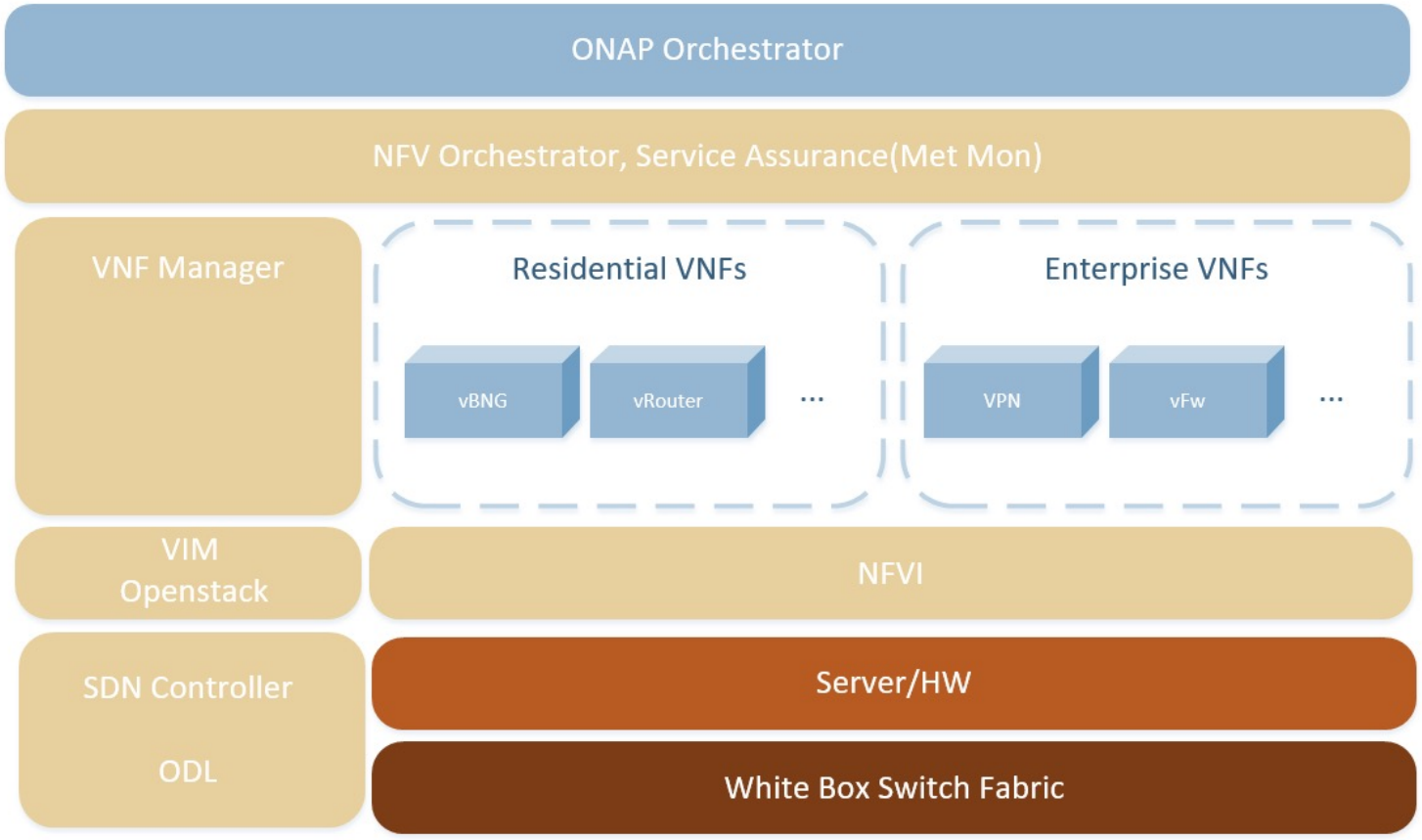
CORD



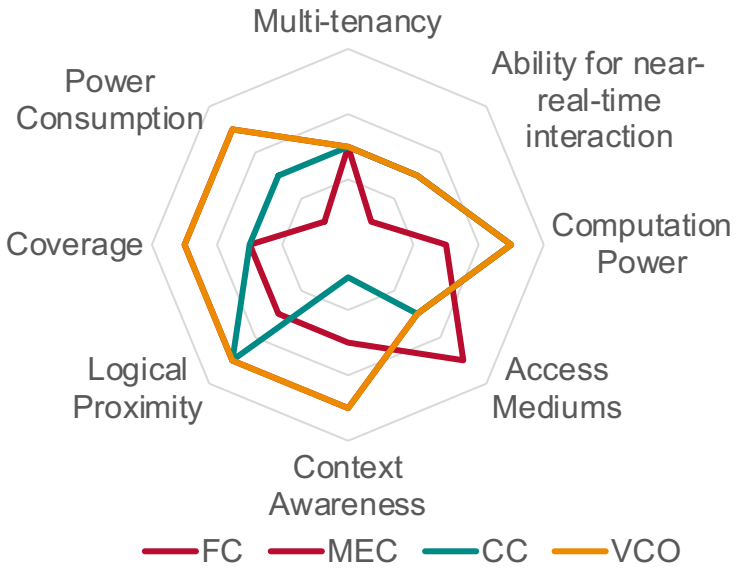
"Manage their Central Offices using declarative modeling languages for agile, real-time configuration of new customer services"



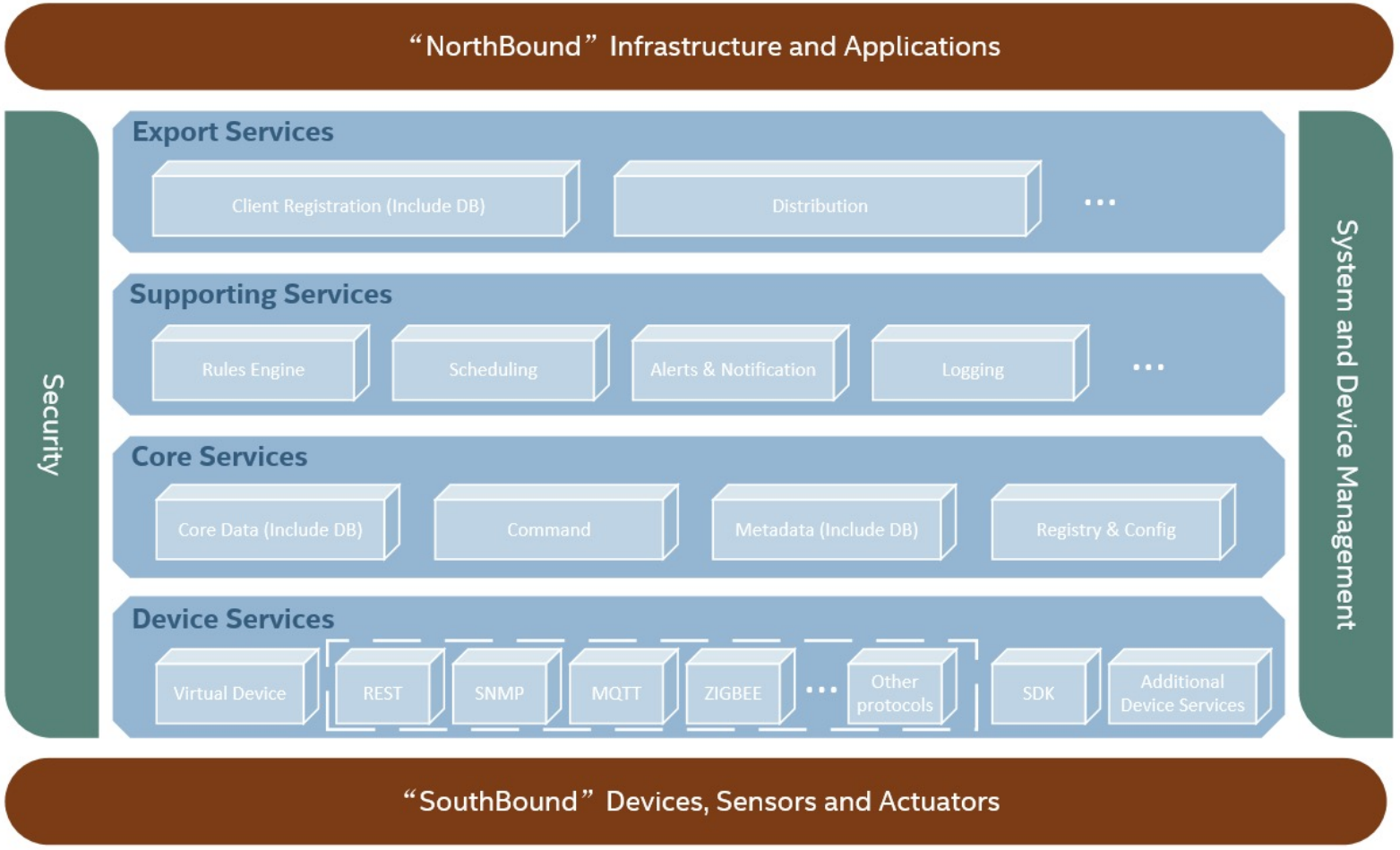
VCO



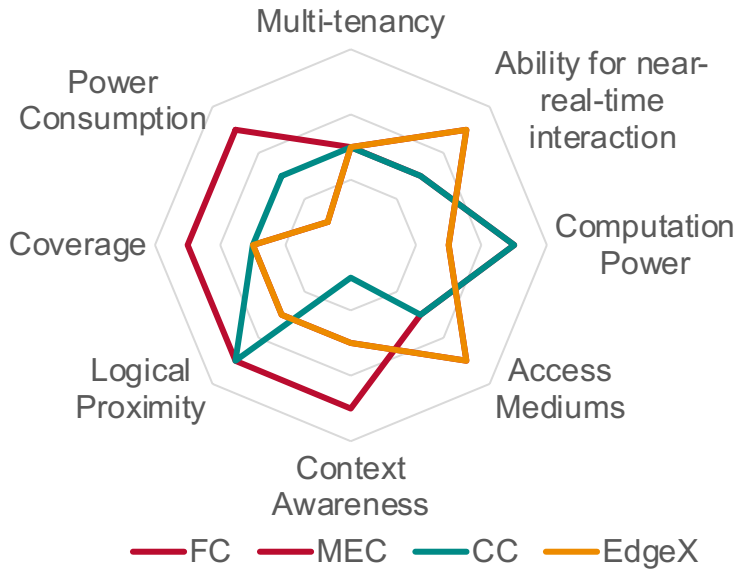
"Successfully completed two demos on residential, enterprise and mobile services "



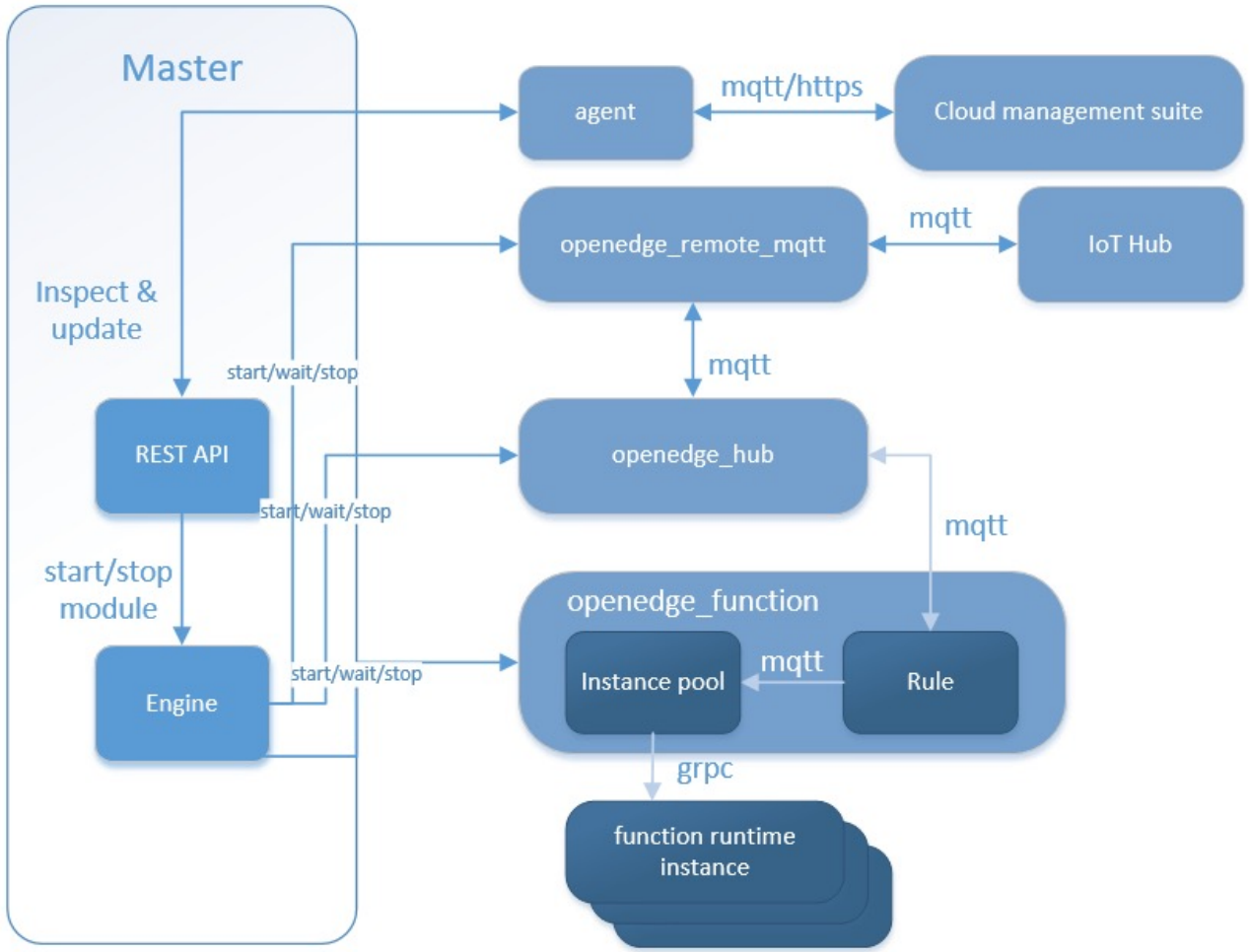
EdgeX Foundry



"Loosely coupled microservice framework with device management and various protocols supported"

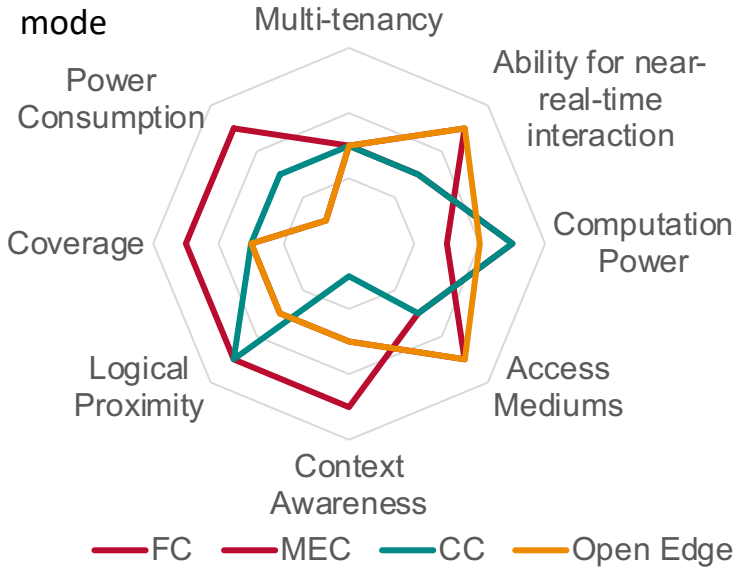


Open Edge

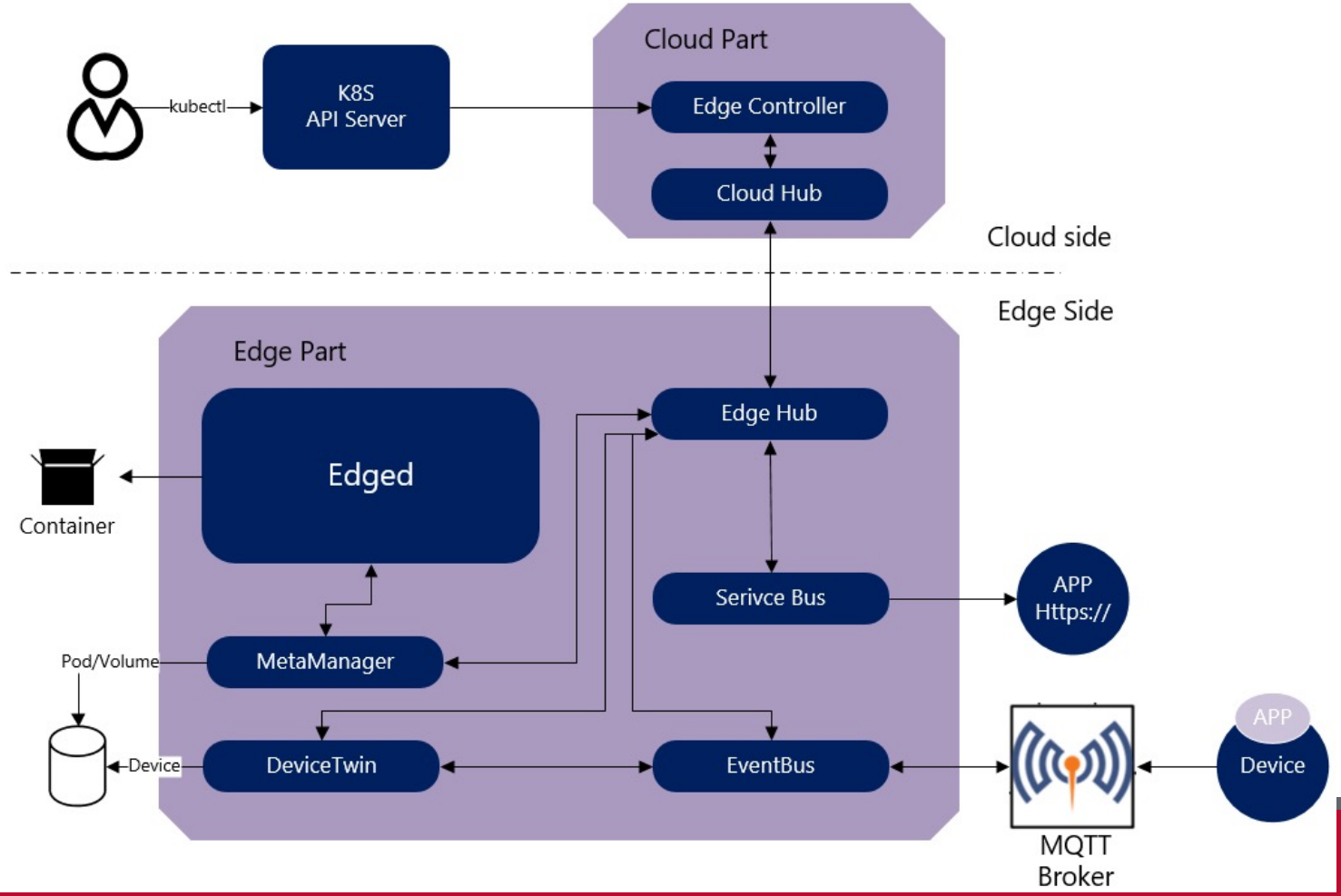


"Open edge computing framework that provide temporary offline, low-latency services, and include remote synchronization, function computing, video access pre-processing, AI inference, etc."

- Already support functions such as python 27, and compatible with Baidu CFC
- Support both containerized mode and normal process mode



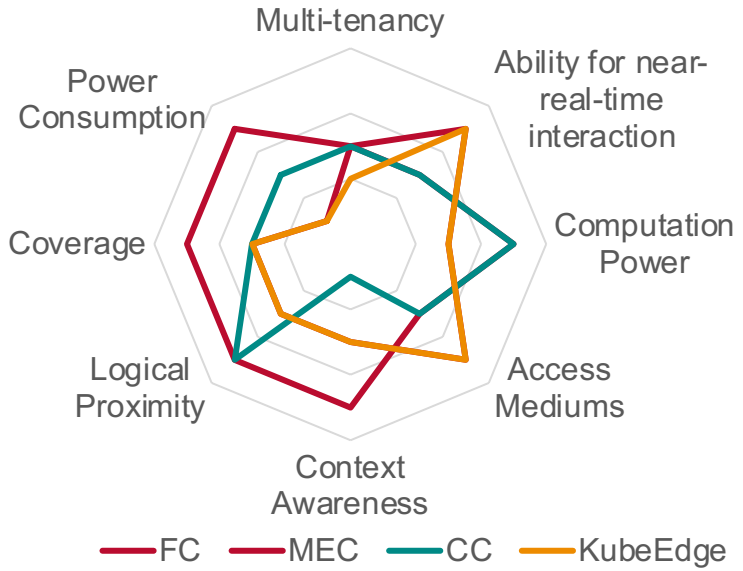
KubeEdge



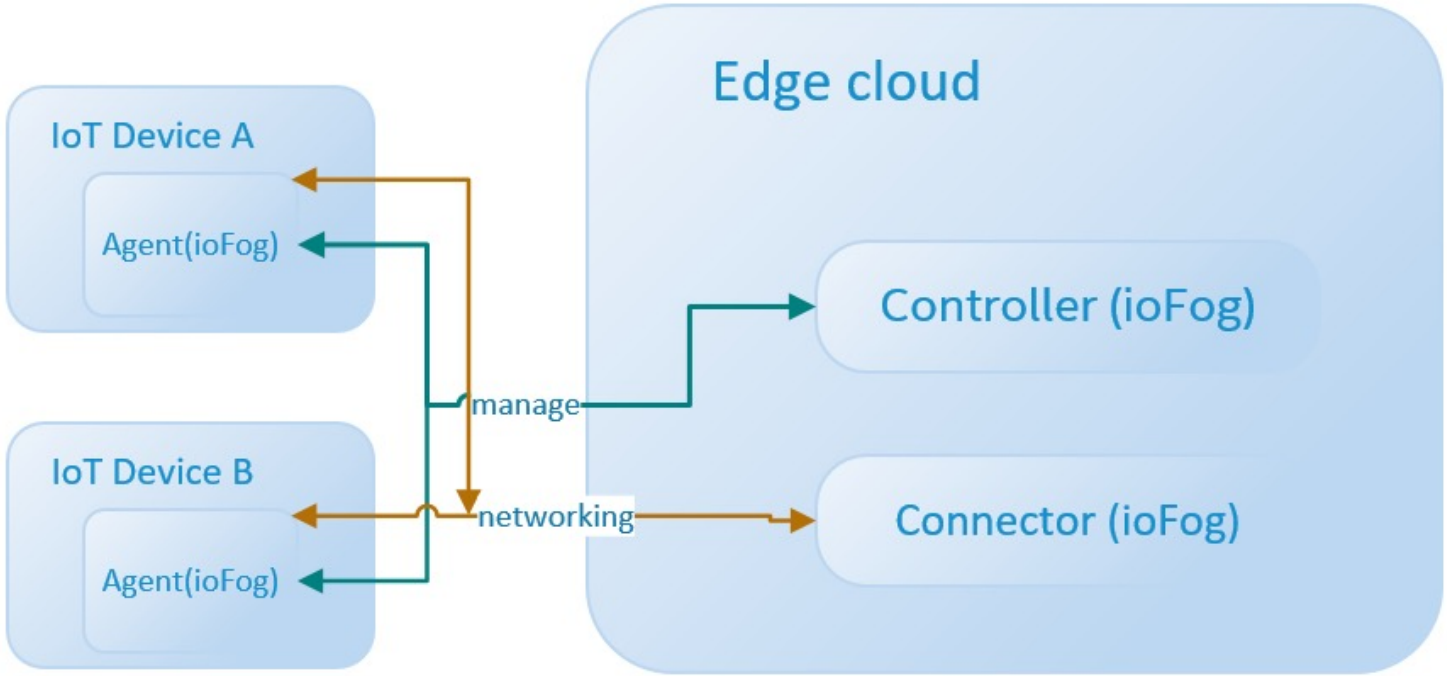
"First Kubernetes Native Edge Computing Platform"

"Small footprint (66MB and ~30MB needed for memory)."

"Easy to enable a mini-cloud at the edge"



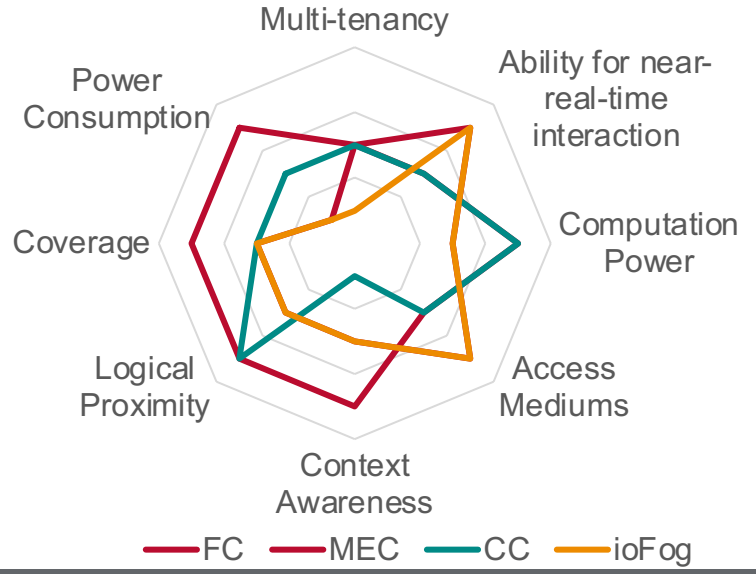
IoFog



"Deploying, running, and networking distributed microservices at the edge"

"Construct an Edge Compute Network (ECN) with Agent, Controller and Connector"

"Need to write microservices for one's own purpose"



Summary of Edge Projects

Project	Foundation	Key Participators	Layer	Segment/Focus	MANO	SDN	Latest version	Infra	Code Repo
Akraino	Linux Foundation	AT&T, Intel, ARM, Nokia, Ericsson, Dell, Red Hat, Juniper, WRS, etc.	Umbrella, Full Stack	All-in-one edge stack	N/A	N/A	N/A	Openstack, K8S	http://gerrit.akraino.org
StarlingX	OpenStack Foundation	Wind River, Intel, Huawei, Ericsson, China Unicom, etc.	IaaS	Industrial IoT and MEC	ONAP	ODL	1.0	OpenStack	https://git.starlingx.io/cgit
Airship	OpenStack Foundation	AT&T, SKT, Intel, Mirantis, etc.	Deployment	Openstack on Kubernetes	ONAP/Tacker	Calico	0.1	OpenStack/K8S	https://git.airshipit.org/cgit
CORD	Linux Foundation	AT&T, SK Telecom, Verizon, China Unicom and NTT, etc.	IaaS	MEC for residential, enterprise & mobile	XOS	ONOS	6.0	OpenStack/K8S	https://github.com/opencord
vCO	Linux Foundation	Red Hat, China Mobile, etc.	IaaS	MEC for residential, enterprise & mobile	ONAP/Tacker	ODL	2.0/3.0	OpenStack	No code repo yet. Just POC

Summary of Edge Projects

Project	Foundation	Key Participators	Scope	Layer	Segment/ Focus	Latest version	Code Repo
EdgeX Foundry	Linux Foundation	Dell, Vmware, etc.	Common framework for Edge solutions (SDK).	PaaS	Industrial IoT	3.0 (4.0 expected in April 2019)	Go: https://github.com/edgexfoundry/edgex-go Java: https://github.com/edgexfoundry
OpenEdge	N/A	Baidu, etc.	Open edge computing framework	PaaS		0.1.2	https://github.com/baidu/openedge
KubeEdge	CNCF, Linux Foundation	Huawei, etc	Extend native containerized application orchestration capabilities at Edge	PaaS		0.2	https://github.com/kubeedge/kubeedge
Azure IoT Edge	N/A	Microsoft	Internet of Things (IoT) service that offload task to edge	PaaS	IoT	1.0.8-dev	https://github.com/Azure/iotedge
ioFog	Eclipse Foundation	Edgeworx, etc.	Edge computing platform through microservice at edge	PaaS	IoT	2.0/3.0	https://github.com/ioFog/iofog.org
Eclipse Kura	Eclipse Foundation	Eurotech, Rad Hat, Comtrade, etc.	Platform for building IoT gateways, enabling remote management & app deployment	PaaS	IoT	4.0	https://github.com/eclipse/kura/
Amazon Wavelength							